Experience of Continuous Expansion of Adaptive Knowledge Assessment System's Functionality Based on Testing Results

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Abstract: *The paper describes evolution of the concept map based adaptive knowledge assessment system. The basic conceptions of concept maps are given, as well as basic principles of the developed knowledge assessment system are presented. Four versions of the system are described showing how their testing results promoted expansion of system's functionality.*
Key words: *Concept Map, Adaptive Knowledge Assessment.*

INTRODUCTION

Nowadays when education from teacher-centered activity has become student-centered activity the use of modern information and communication technologies in teaching and learning is a conventional and habitual practice. Not only teaching/learning has changed, but also new trends have emerged into students testing, their knowledge assessment and scoring. Introduction of such terms as computer-based assessment, e-assessment, online assessment, and others may be considered as conclusive proof of recent trends. At the same time, with the dissemination of different forms of technology-enhanced learning, for instance, e-learning or m-learning, learning assessment has become a constant concern [1]. Mainly two reasons are mentioned: lack of needed adaptivity and regularity of knowledge assessment. Even in traditional teaching and learning, where adaptive and regular knowledge assessment may be carried out quite naturally, usually only final tests and/or examinations are applied in practice due to the high workload of teachers. The same to the large extent is true also for computer-based assessment.

Traditionally it is based on tests where students receive a set of questions with already pre-defined answers [2]. Questions mainly are multiple choice or multiple response questions, graphical hotspot questions, fill-in-blanks, text/numerical input questions and matching questions [3]. The well known and widely used e-learning systems Blackboard (www.blackboard.com) and WebCT (www.webct.com) have built-in mechanisms to operate with tests. Along with indisputable advantages, such as greater flexibility regarding place and time of assessment, providing assessment for large number of learners, instant feedback to learners [4], etc., these systems don't exploit all possibilities that can be offered by computer-based testing. That is why computer-assisted adaptive testing based on Item Response Theory appeared in [5]. In this approach students receive more difficult or easier test items, depending on their previous testing results, i.e. the sequence of test items depends on the answer given to the previous test item. Thus, students' knowledge levels are more accurately estimated reducing negative psychological effects [5]. Besides, tests are shorter because fewer items are needed to obtain reliable results about students' knowledge level.

Despite of the range of abovementioned advantages even the usage of adaptive testing doesn't support sufficiently wide and comprehensive knowledge assessment. Being explicit, tests don't allow to assess student's knowledge structure, i.e. how he/she understands relations between concepts or how new concepts are connected with previously mastered concepts [6, 7].

The paper presents experience obtained from the use of the concept map based adaptive knowledge assessment system (KAS) [6]. The KAS has been tested in several engineering courses and learners' feedback has been collected allowing continuously extending system's functionality. The remainder of the paper is organized as follows. The next section introduces basic conceptions of concept maps and the KAS. After that it is described how the KAS has evolved during the years of its development. The key issues found from the feedback given by learners are highlighted which were used for expansion of functionality of the KAS. Conclusions and future work are given in the last section.

BASIC CONCEPTIONS OF CONCEPT MAPS AND THE DEVELOPED KNOWLEDGE ASSESSMENT SYSTEM

Most cognitive theories share the assumption that concept interrelatedness is an essential property of knowledge [8]. Cognitive theory underlying concept mapping grew out of Ausubel's Assimilation Theory [9, 10] and Deese's associationism memory theory [11]. The former postulated a hierarchical memory structure, whereas the latter postulated a network of concepts. A concept map (CM) – a pedagogical tool developed by Novak [12, 13] – is based on both abovementioned theories. According to Novak, a CM represents a part of an individual's cognitive structure, revealing his/her particular understanding of a specific knowledge area. Essentially CMs are a specific kind of mental models that are used for representing and measuring of individual's knowledge level. Mathematically defined and visualized, a CM is undirected or directed graph consisting of a finite, non-empty set of nodes which represent the concepts of a knowledge domain, and a finite, non-empty set of arcs (undirected or directed) which represent the relationships between pairs of concepts. Arcs may have the same or different weights, i.e., from the teacher's (expert's) point of view some relationships may be more important than others [14]. A CM can be defined also as an attributed graph (attributes can be words or linking phrases (propositions) used to specify the kind of relationship between concepts [15]). A proposition is a semantic unit of CM, i.e., a concept-relationship-concept triple which is a meaningful statement about some object or event in a problem domain [16]. An example of CM constructed for the subject "Systems Theory Methods" is given in Figure 1.

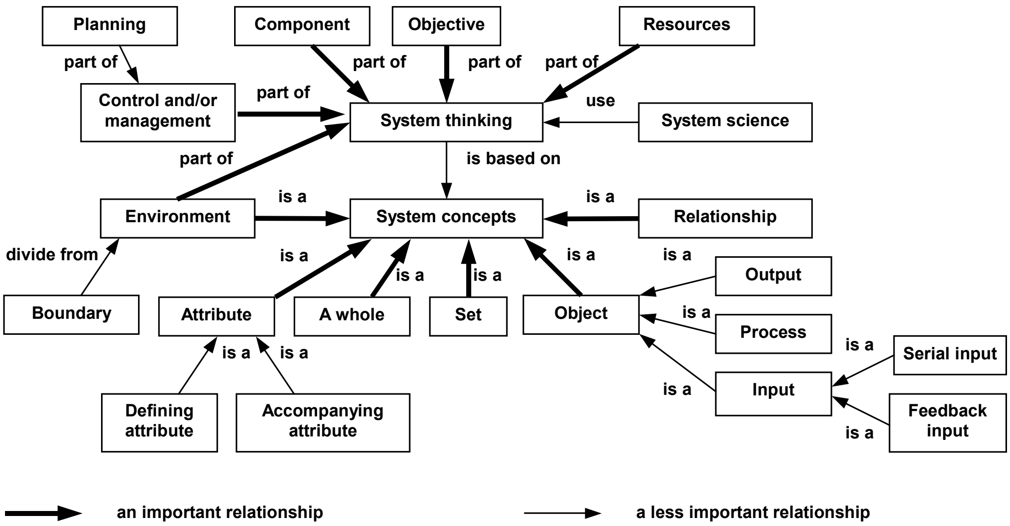

Fig.1. An example of concept map visualized by directed weighted attributed graph

The developed adaptive KAS consists of three modules (Figure 2) and is implemented as a multiagent system [6, 17]. The administrator's module allows managing data about users (learners and teachers) and studying courses providing functions of data input, editing, and deleting. The teacher's module supports teachers in construction of CMs. It provides editing and deleting of CMs, evaluation of learners' completed CMs and assigning the scores which characterize the level of correctness of learners' CMs. The learner's module includes tools for completion of CMs given by a teacher and for viewing feedback after the solution is submitted. The modules interact sharing a common database where data about teachers and their courses, learners, teacher created and learners' completed CMs, as well as learners' final scores are stored (Figure 2).

The developed system supports the following scenario. A teacher divides a study course into N stages and defines all concepts and relationships between them. The system supports teacher's actions for drawing CMs for each stage on the working surface. During knowledge assessment or self-assessment learners get a task (a CM) that corresponds to the current stage of learning process. After finishing the completion of CM, a learner confirms his/her solution and the system compares CMs of the learner and the teacher on the basis of patterns of learners' solutions [18]. The final score and the learner's CM are stored into the database, and a learner receives feedback about correctness of his/her solution.

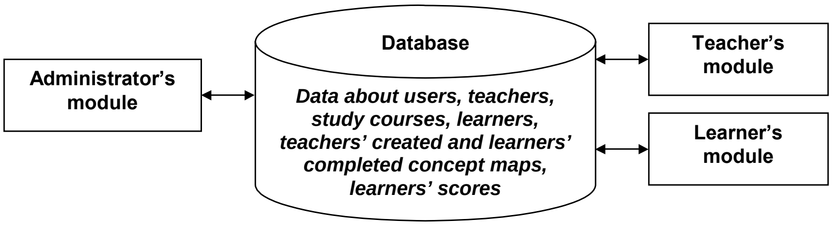

Fig.2. The system's architecture in terms of modules

EVOLUTION OF ADAPTIVE KNOWLEDGE ASSESSMENT SYSTEM

The development of the adaptive KAS started in 2005, and at present four projects has been finished. The development of KAS is based on a framework for conceptualizing CMs as a potential assessment tool proposed in [8]. According to the framework an assessment is considered as a combination of a task given to a student, a format for a student's response, and a scoring system by which students' CMs can be evaluated. In the developed KAS tasks vary depending on task demands and task constraints. Two classes of CM tasks, namely, fill-in-the-map and construct-the-map are used. Learners are or aren't provided with lists of concepts and/or labels for the links, as well as asked to fill-in the blank CM or to draw it. Actually the first version of KAS was not adaptive at all because learners could solve only fill-in-the-map tasks receiving the same given CM structure. The task was to put concepts from a given list in correct places (nodes). There were limited possibilities to change the degree of task difficulty by increasing or decreasing the number of teacher's predefined concepts already placed in correct places. Arcs were undirected and without linking phrases, but two weights reflecting importance of relationships (important and less important) were used. The algorithm for comparison of CMs has been developed and implemented which is sensitive to the arrangement and coherence of concepts (for details see [17, 18]). When comparison is finished a learner receives feedback with information about incorrectly related pairs of concepts, a list of concepts, which are not inserted, the maximal possible score for the absolutely correct solution, and the achieved actual score. The teacher receives feedback with information about the scores of all learners and their CMs with mistakes highlighted on them [17].

To get the feedback from students the questionnaire was worked out which included 15 questions mainly targeted towards functionality of KAS and easiness to understand and complete CM tasks. The KAS was used in 6 study courses (5 engineering and 1 pedagogical course) both in Riga Technical University and Vidzeme University College. In total 95 students used the KAS and 84 of them submitted the questionnaire. Fifty three (63%) students answered that CM tasks promote logical thinking and better understanding of learning contents. They stressed that CMs helped them to get the knowledge structure. Forty four (52%) students found that fill-in-the-map tasks were difficult, and for six (7%) of them even very difficult. They also reveal causes: the approach is unusual, requires active thinking and the KAS has limited functionality.

The students pointed out that textual format of feedback isn't informative enough, and suggested to elaborate the feedback in order to identify mistakes in a graphical form. They also suggested using drag-and-drop technique.

Based on students' evaluation several new solutions were implemented in the second version of KAS. First, more informative feedback for teachers and learners was implemented. For teachers the system collects statistical data about non-existing links that learners often define, about correct links that learners define rarely, and about incorrect weights of particular links. The feedback for learners was more instructive and was given in a graphical form. A learner receives his/her completed CM with labels representing received points for each link.

Second, two approaches for changing the degree of task difficulty were developed, namely, inserting additional concepts into a CM by the system or offering different types of tasks. In the first approach only fill-in-the-map tasks are used, and a learner can ask to reduce the degree of task difficulty. The agent-expert uses the developed algorithm, identifies degrees (the number of incoming and outgoing arcs) of free nodes (nodes where concepts are not placed yet), and sorts them in descending order. The node with an average index is chosen and the KAS inserts the corresponding concept into a learner's CM. Nodes with an average degree are inserted first (the decision is based on the assumption that concepts with smallest degree give too little help, but concepts with highest degree are keywords that learners must know). This approach was evaluated in 4 study courses (3 engineering and 1 pedagogical) both in Riga Technical University and Vidzeme University College. Forty four students took part, and 35 questionnaires were received after knowledge assessment. The questionnaire included 17 questions. Questions about new possibility offered by the system to reduce the degree of task difficulty were added. Students were asked did they use it, and if not, why. In this experiment 26 (74%) students answered that CMs help them to understand learning material better, but for 21 (60%) student CM tasks were difficult, and for 4 (11%) very difficult. At the same time only 10 (29%) students used the system's offered possibility to reduce the degree of task difficulty, while others answered that they didn't want to reduce their total score. Practically all students found the new graphical interface convenient, perceivable, and demonstrative. Twenty seven (77%) students indicated that system's provided feedback was useful showing what kind of knowledge is missing. So, evaluation of feedback was significantly higher in comparison with the first version of the KAS.

In the second approach 3 fill-in-the-map and 2 construct-the-map tasks are used starting with high-directed one where a structure of a CM, which is visualized as an attributed graph, is given, and ending with low-directed task where a CM must be drawn in case if only a list of concepts is given [20]. A learner receives a task that has a teacher's defined degree of difficulty. During the task performance a learner can ask to reduce the degree of task difficulty or depending on learner's results the system can do it. If a learner has reached a teacher's predefined minimal score without reduction of the task difficulty, the system delivers more difficult task at the next stage. This is the KAS's adaptive mechanism. The second approach was evaluated using the KAS for one engineering course "Fundamentals of Artificial Intelligence". Totally 30 students participated and 28 questionnaires were received. Again approximately the same number of students (19 or 68%) answered that CM tasks helped them to understand better logical organization and interconnectedness of mastered concepts. Sixteen (57%) found CM based tasks difficult, and 12 of them used possibility to reduce the degree of task difficulty. The system increased the task difficulty for 9 students. Questionnaires reflected suggestions of students among which the most significant were option to define synonyms of concepts and linking phrases and possibility to used directed graphs which may make easier the task of definition of linking phrases.

These suggestions which were implemented in the third version of the system promote further expansion of KAS functionality. Besides, a set of standard linking phrases was defined, such as "is a", "is instance of", "has attribute", "has value", and "part of". Performance of the third version was evaluated in the study course "Systems Theory Methods" by 40 students. In 37 submitted questionnaires with 22 questions (3 questions were added asking about suggestions how to improve the feedback) there were 57% answers that for 21 student it was difficult to solve given CM based tasks, while 16 (43%) of them found it easy. As the main reason of difficulties in 10 questionnaires was mentioned insufficient learner's support from the system's side. Students wanted to get some learning material from the KAS if they have difficulties to solve the task.

Thus explanation of the concept is added in the fourth version of the KAS. Students may receive explanations in three forms – a definition, a short description or an example of concept. The initial form of explanation is chosen by a learner who can change it during solution of CM task. Moreover, the system keeps track of learner's actions and determines which form of explanation has the greatest contribution to creation of correct CM. This, in turn, enables modification of student's model. This version was evaluated using more informative questionnaire that contains 33 questions. Students were asked for their opinion, for example, why they found working with CMs difficult or easy, did they find that after the reduction of task difficulty they really received easier task, did provided explanations helped to solve the task, etc. The version was tested by 36 students who learned "Systems Theory Methods". It is interesting to point that rather frequently students found that for them construct-the-map task with given list of concepts seemed more easy than fill-in-the-map task in which linking phrases must be defined. Testing of the fourth version of KAS shows that approximately the same number of students used each of the proposed explanation forms. At the same time they found that definitions are the most useful for better understanding but examples were not helpful enough.

At the moment the fourth version of KAS is transformed into new three-tier architecture for security reasons [18]. This new version is implemented using the following technologies: Eclipse 3.2, Apache Tomcat 6.0, Posture SQL DBMS 8.1.3, JDBC drivers, Hibernate, VLDocking, JGoodies and JGraph.

CONCLUSIONS AND FUTURE WORK

The paper reflects the experience get from testing four versions of adaptive KAS in different study courses. Testing results allowed step-by-step to expand functionality of the developed system. Obtained experience manifests that the KAS based on CMs helps students better to understand learning contents. In all testing experiments in average around 75% of students liked the usage of CMs for knowledge assessment and they wanted to use this approach in other courses, too. At the same time it turns out that considerable number of students (more than 55%) found that CM based tasks are difficult for them. As main reasons of difficulties insufficient learner's support from the system's side, lack of work experience with CMs and insufficient knowledge of learning material are mentioned more frequently. Contrary, those students who didn't have problems stressed that they have good understanding of nature of CMs, have experience of drawing different diagrams and using many software products, as well as have good knowledge.

It is interesting to stress that engineering programme students who study computer science achieved considerably higher scores in comparison with students of pedagogical programme. The working hypothesis is that computer science students are familiar with various diagrams used in software engineering therefore a CM is not a new technique for them, but more experiments are needed for acceptance of it.

These testing results have inspired the developers of KAS to continue its improvements. Future work is directed towards extension of the developed KAS. The algorithm for transformation of study course ontology into CMs should be integrated into the system. New algorithms for more efficient CMs comparison should be developed and implemented, too. Moreover, more rich and complete student model should be developed and used. And last but not least, a scoring system by which students' CMs can be evaluated accurately and consistently, taking into account various cases of reduction of the degree of task difficulty should be worked out.

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